CANNIBALISM AND PREDATION BY WESTERN TOAD (*BUFO BOREAS BOREAS*) LARVAE IN OREGON, USA

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Larval amphibians have been widely used as model organisms in studies of community ecology of freshwater systems (Morin 1983, Alford 1999). Much of this work has assumed that trophic effects of larval anurans are focused on periphyton and planktonic algae (Dickman 1968, Seale 1980, Duellman and Trueb 1986), a view that has recently been questioned. Recent experiments suggest that anuran larvae can occupy broader trophic roles than previously believed and may function as important predators in some pond communities (Petranka et al. 1994, Petranka and Kennedy 1999).

Reports of larval cannibalism and predation among anurans have been restricted to the genera *Rana* (family Ranidae) and *Scaphiophus* (Pelobatidae) (Bleakney 1958, Bragg 1964, Petranka et al. 1994, Alford 1999, Petranka and Kennedy 1999). Several members of the genus *Bufo* (Bufonidae) are known to cannibalize eggs (*Bufo calamita,* Banks and Beebee 1987; *B. arenarum,* Crump 1992; *B. terrestris,* Babbitt 1995) or to consume invertebrate or larval fish prey (Diaz-Paniagua 1989, Nguenga et al. 2000). However, published reports of larval cannibalism and predation on amphibian prey in the family Bufonidae are limited to a single laboratory study (*B. bufo,* Nagai et al. 1971). Field observations of cannibalism or interspecific predation by larval bufonids have not been reported. Here we report field observations of cannibalism by larval western toads (*Bufo boreas boreas*), as well as predation by *B. b. boreas* larvae on larval and metamorphosing Pacific chorus frogs (*Pseudacris regilla*) and Cascades frogs (*Rana cascadae*) in the Cascade Mountains of Oregon, USA.

On 12 July 2001, DJJ and CJR observed high densities of anuran larvae of 3 species (*B. b. boreas, P. regilla,* and *R. cascadae*) at West Snow Lake (43°02.05′N, 122°29.13′E; elev. 1460 m). The lake had dried down to a pool ca. 40 × 20 m with a maximum depth of ca. 1.5 m. Our visual survey of the site yielded the following abundance estimates: 9,000 *B. b. boreas* larvae (mean snout-vent length (SVL) = 12.0 mm, $n = 10$); 34,000 *P. regilla* larvae, metamorphs, and juveniles (mean SVL = 10.0 mm, $n = 10$); and 26,000 *R. cascadae* larvae, metamorphs, and juveniles (mean SVL 21.0 mm, $n = 10$). Most feeding *B. b. boreas* tadpoles were engaged in typical benthic scouring, with lesser numbers grazing the underside of the surface film. During our survey we observed 5 *B. b. boreas* tadpoles feeding on live, apparently uninjured conspecifics in shallow (25 cm) water ca. 45 cm from shore. We observed 2 additional *B. b. boreas* larvae (SVL ca. 12 mm) pursue and attack a conspecific that was swimming weakly in 20-cm-deep water. Within 30 seconds, another ca. 10 *B. b. boreas* larvae were feeding on the injured larva. Viscera and recently erupted rear limbs were consumed first, and the entire larva was consumed within ca. 90 seconds. We observed 12 similar cannibalistic aggregations of *B. b. boreas* larvae in the pool, all of which were located 35–45 cm from shore in water 20–30 cm deep.

We (DJJ and CJR) also observed *B. b. boreas* larvae prey upon 1 live *R. cascadae* larva (SVL ca. 22 mm) and 1 live *R. cascadae* metamorph (SVL ca. 18 mm). The *R. cascadae* larva and metamorph were both initially attacked by 1 *B. b. boreas* larva. In both cases we observed small aggregations of *B. b. boreas* (5–7 larvae)

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feeding on the *R. cascadae* within 60–70 seconds of the initial attack. No injuries were observed on the *R. cascadae* larva or metamorph prior to either attack.

During the same survey we observed *B. b. boreas* larvae pursue and attack 5 *P. regilla* metamorphs (SVL ca. 10 mm). These attacks were similar to the previously described *R. cascadae* attacks, with 1 *B. b. boreas* larva making the initial attack and other *B. b. boreas* larvae arriving after that initial contact. In addition, we observed 4 aggregations of 3–4 *B. b. boreas* larvae feeding on 2 live and 4 dead *P. regilla* larvae (SVL ca. 8 mm). We observed no signs of injury or weakness in the 2 live *P. regilla* larvae during our observations. All observed instances of *P. regilla* predation occurred within 30 cm of shore in water that was 10–15 cm deep.

Larval *B. b. boreas* cannibalism was also observed in Big Lake (44°22.50′N, 121°51.91′E; elev. 1407 m) on 3 July 2001. While sampling a shallow, sparsely vegetated bay, DJJ and another surveyor observed 13 aggregations of 5–10 *B. b. boreas* larvae. Ten of these aggregations appeared to be feeding on deceased conspecifics and 3 on live *B. b. boreas* larvae. To examine potential attraction to conspecifics, we collected 5 dead *B. b. boreas* larvae from dried peripheral pools. We placed 1 larva within 30 cm of each of the aforementioned larval aggregations. Soon after introduction (mean = 116 seconds; range 93–151 seconds), 3 or more live *B. b. boreas* from larval aggregations began feeding on the dead larva. In each case at least partial consumption of the skin of the deceased larva was observed.

We (BM and CJR) made a 3rd observation of cannibalism by larval *B. b. boreas* on 17 July 2003 at Frying Pan Lake (50°04.30′N, 59°49.26′E; elev. 1227 m). Water depth in Frying Pan Lake was reduced 75–100 cm (ca. 40%–50%) below levels observed during summer 2002. We estimated that ca. 80,000 larval (mean SVL = 15.0 mm, $n = 8$) and ca. 120,000 recently metamorphosed *B. b. boreas* (mean SVL = 14.5 mm, $n = 5$) were present at the site. Most larvae that we observed feeding appeared to be grazing slowly over flocculent organic sediments. A smaller number of larvae were grazing along pondweed (*Potamogeton natans*) leaves and sedge (*Carex* sp.) stems.

While surveying, we observed 5 *B. b. boreas* larvae (SVL ca. 15 mm) converge on and completely consume a weakly swimming conspecific larva of similar size as its attackers. The attack lasted ca. 180 seconds and occurred in shallow water ca. 1 m from an aggregation of ca. 5000 *B. b. boreas* larvae. Later during the same survey, we observed a *B. b. boreas* larva (SVL ca. 15 mm) swimming at the water surface above a living transformed *B. b. boreas* juvenile of similar SVL. Closer inspection revealed that the larva was holding the juvenile by the gular region and had already removed the skin and rasped away some of the underlying tissue. During 15 minutes of observation, the juvenile *B. b. boreas* gradually ceased struggling. By the end of this period, the larva had consumed a significant amount of tissue from the juvenile's gular region.

High larval densities and scarce food resources have been associated with cannibalism and predation among non-bufonid anuran larvae (Bragg 1946, Crump 1983). Water levels at all sites in this study were substantially reduced by low winter precipitation. In particular, the winter of 2000–2001 was the 2nd lowest snowpack in 20 years (63% of the 20-year mean) in the central Oregon Cascades (Irish-Taylor Snotel station; http://www.wcc.nrcs.usda.gov/snotel/Oregon/oregon.html). Reduced water volume in montane lakes can concentrate anuran larvae in lake centers where macrophytic vegetation is often less abundant than in peripheral fringes (C. Pearl and B. McCreary personal observation). The small sizes of larval and metamorphic individuals of the 3 anuran species in West Snow Lake are consistent with a food-limited system (see Wilbur 1977). We hypothesize that the combination of high larval densities and food limitation may have triggered the predatory behaviors we observed.

Larval cannibalism can confer growth or survival benefits to those individuals that consume conspecifics in amphibians (Bragg 1964, Nagai et al. 1971, Crump 1990, Wildy et al. 1998). In addition, cannibalism has been linked with accelerated metamorphosis in salamander larvae (Lannoo et al. 1989). Whether this occurs with *B. b. boreas* during low water conditions merits further investigation. Our observations of *B. b. boreas* cannibalism and predation support Petranka and Kennedy's (1999) assertion that anuran larvae may at least occasionally exercise trophic effects beyond their traditionally accepted role as herbivores.

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